Publications Committee

University of Texas Bulletin

No. 1770: December 15, 1917

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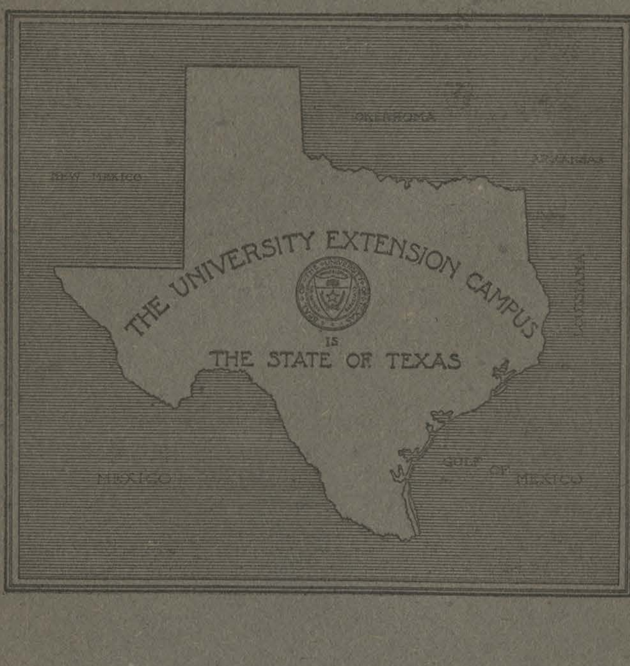
BY

E. E. DAVIS

Lecturer on Rural Education
in the Department of Extension



Published by the University six times a month and entered as
second-class matter at the postoffice at
AUSTIN, TEXAS

Publications of the University of Texas

Publications Committee:

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B298-918-6m

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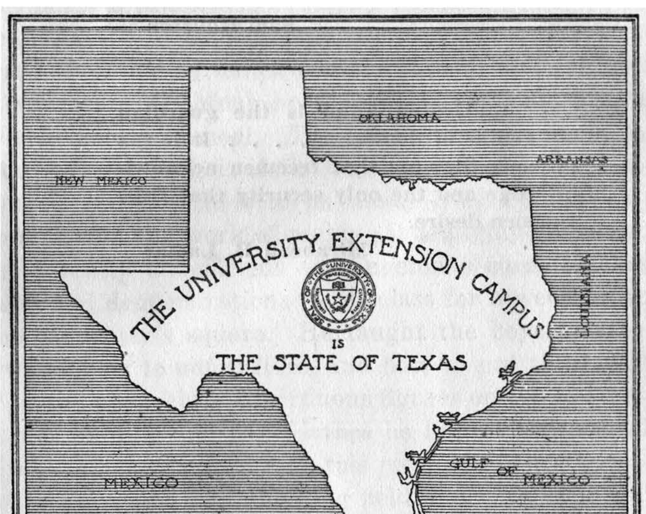

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

PREFACE

Elaborate physical equipment is beyond the reach of many country schools. But standard equipment is not absolutely essential for the teaching of many lessons in the elementary sciences if the teacher knows how to organize and use the material for instruction that nature has everywhere so generously provided. The keys that unlock the doors to scientific truth can be found on every country hillside, in the meadow, by the brook, at the mill, in the poultry yard, at the dairy barn, and at every other point in our physical environment. But, to be of value in instruction, the teacher must know how to recognize them and use them intelligently.

Concrete illustrative material taken fresh from the fold of nature is often preferable to highly polished pieces of factory-made apparatus. High-priced, complex apparatus sometimes distracts the mind of the elementary student and confuses facts with appearances. Much home-made equipment is highly desirable in a rural school. The boys will give much valuable assistance in making it if the teacher will only explain what is wanted and how it is to be used. Such equipment is not expensive, and the work of making it is highly educational.

But recently an efficient and ingenious rural teacher gave lectures and demonstrations to his class for a week on the uses of the carpenter's square. He taught the boys how to build stairways, how to cut rafters, and how to put to practical use most of the apparently superfluous figures on the square. Then with a plumbline and some lathes he improvised a crude sort of level. After school he took this piece of apparatus and went with the boys into a neighboring field and with their assistance established the lines on which terraces for the farm were subsequently constructed. Many other school lessons were taught in a similar way.

The children of the upper grades in this excellent country school had a clearer insight into the applied problems of physics, mathematics, and agriculture, than is true for the pupils of the corresponding ages and grades in many of our well-equipped city high schools. Their instruction was simple, concrete, and practical. Its simplicity and its relation to the immediate needs of that community gave it a vitality and richness of interest seldom enjoyed by high schools with more pretentious equipment.

The methods of instruction in most of our country schools are greatly in need of reform. Especially is this true of the science instruction in the elementary grades. The great wealth of concrete material so rich in educational values in every country district remains, for the most part, unused and unseen by most country teachers. Very few country schools in Texas have yet acquired any real character of their own. Most of them are just poor copies of city schools conducted in the country. It is hoped that the suggestions in this bulletin will be helpful to all teachers interested in adapting their elementary science instruction to country conditions and needs.

In the preparation of the chapters on physical geography and physiology I have adhered rather closely to the contents and general outlines of the texts now adopted for use in the public schools of Texas. Personally, I would have preferred more freedom in my choice of material for these two chapters; but, knowing that in practice most teachers follow the texts very closely, I thought best to make the experiments and demonstrations I chose accord as close as possible with the lessons they will most likely teach.

E. E. DAVIS.

CONTENTS

PHYSIOLOGY

No subject of science ranks higher in practical importance and lower in the quality of instruction given in the rural public schools than physiology. This subject can not be adequately taught from text-books, and so far but few teachers have had the time, inclination, and ingenuity to adopt the laboratory method of study. It is true that in most of the consolidated rural and village schools for which this bulletin is intended, there is no laboratory apparatus. But for the teacher who is capable and industrious, and prefers to go to nature rather than to the textbook for his material for instruction, much of this handicap can be very easily removed. With a fully equipped laboratory and plenty of time, it is best to have the pupils do the laboratory work. But when the teacher with a limited amount of time and equipment does the work in the presence of the class, he makes a great step in advance of the traditional text-book recitation.

The science of physiology is of such a nature that much of the material for demonstration work and laboratory examples can be provided at very small cost. For all those who teach in schools with meager equipment and appreciate the great value of laboratory methods, the following suggestions as to simple experiments and inexpensive equipment will be very helpful.

List of Equipment

Scalpel or sharp pocket knife
Small scissors with sharp point
Bone forceps
Skulls and skeleton of small animals
Ball and socket joint, long bones, flat bones
Hydrochloric acid, ½ pt.
Nitric acid, ½ pt.
Three feet of ⅛-in. rubber tubing
Three feet of ⅛-in. glass tubing.
Fehling's solution, 1 oz.
Test-tubes, 1 doz.
Alcohol lamp.
Wood alcohol, 1 pt.
Formalin, 1 qt.
Ammonia, ½ pt.
Iodine, 1 oz.
Glass fruit jars.
Glass tumblers.

This equipment can be purchased for four or five dollars. While attending teacher's institute, get catalogues and price lists from some high school science teacher and make up your order. Sometimes you can purchase a few small items such as rubber-tubing, and test-tubes from a well-equipped high school laboratory. Most high school teachers of science will be glad to assist you in procuring the things you need.

SOME SIMPLE MATERIAL AN ENTERPRISING TEACHER CAN COLLECT

a. Some enterprising boy will prepare the skeleton of a cat and bring it to school if he is told how. He may not be able to mount it in a way acceptable to a first-class museum, but he can proceed as two boys did for the author on a holiday one time. It was as follows: A large cat was chloroformed, skinned, the viscera carefully removed so as not to injure the cartilage of the breast bone, and as much flesh as possible removed from the bones with scissors and a sharp knife. To remove the remaining flesh it was boiled in a concentrated soap solution until the flesh and most of the ligaments could be easily removed from the bones. The brain and spinal cord were removed and the spinal vertebrae strung on a wire. All the bones of the skeleton were not disarticulated but most of them were. Then they were given a final cleaning with soap and a bristle scrub brush. Later they were put into a cigar box and brought to school. It took the boys just four hours to do this, but it was worth the time.

That same year when some skeletons of mice, rats, frogs, and sparrows were wanted a boy said in class one day, "Why don't you skin them, remove as much flesh as you can conveniently, and put them in a 'red ant' bed? The ants will do the rest." The suggestion was followed and proved a complete success. Place a carcas under a wire net so instruders will not carry it away and give the ants ten days of good sunshine. They will do the rest and do it well. They will rid the bones of all flesh and leave the skeleton completely articulated.

b. Secure a good specimen of a large ball-and-socket joint, a flat bone, and a long bone. Have some boy take a saw and prepare a cross section and a longitudinal section of a round hollow bone. Bones of all descriptions may be collected from the butcher shop and from dead animals about the fields. In both instances it is well to boil them thoroughly in soapy water to sterilize and remove the grease before handling at class.

c. A collection of skulls, including the dog, cat, squirrel, rabbit, and sheep, should be made for the school museum. The pupils will collect a valuable museum if the teacher will lead the way by indicating what things are needed and how they are to be used.

d. Procure a handful of human teeth from some dentist. Sterilize them by boiling. Then have some boy grind them on a grindstone so as to show cross sections of the roots and crowns and longitudinal section of the entire tooth. Make a longitudinal grinding through a gold filling in a tooth so as to show how the filling is retained.

e. Collect the brains of birds, cats, rabbits, squirrels and other animals and preserve in a 5% formalin solution. A fresh brain is very delicate and soft, but the formalin will make it firm in a few days. Use bone forceps in removing the skull from the brain.

f. Remove the skin from the foot and drumstick of a chicken. Beginning with the tendons in the lower part of the leg dissect very carefully with scalpel and sharp pointed scissors, following each tendon back to its controlling muscle in the drumstick. Carefully separate as many of the muscles of the drumstick as possible, leaving them attached to the tendons upon which they act. Preserve the specimen in a five per cent formalin solution in a common glass fruit jar and set aside for use when needed. With the aid of this specimen at class show how the movements of the toes come from the muscles of the drumstick acting upon the long tendons attached to the bones of the toes. Show that in a similar way the fingers of the human hand are moved by the muscles of the fore arm acting upon long tendons, some of which can be seen just beneath the skin on the back of the hand.

g. Secure the body of some vertebrate animal, preferably a rat or a cat. Open the ventral cavity of the body and call attention to how the diaphragm divides it into an upper chamber and a lower chamber designated as the thoracic cavity and the abdominal cavity respectively. Find the heart, lungs, liver, stomach, spleen, kindneys, small intestine, and large intestine. Show that these organs are arranged in the same order as those of the human body shown by Ritchie Fig. 9, p. 17.

A country school very seldom has modern facilities for killing, injecting, and preserving laboratory specimens. For that reason fresh specimens have to be used. To obviate the sight of blood at class, pull the walls of the opened body apart and fasten them down to a board securely with carpet tacks and put cotton over any blood that may show. Make this preparation in the afternoon after school closes or in the morning before school opens.

h. Remove from a cat the entire alimentry tract with the liver and pancreas attached. Make a study of the following points of interest: esophagus, stomach, liver, gall bladder, gall duct, pancreas, pancreatic duct, pylorus, small intestine, mesentery, and large intestine. Call attention to the similarity of this specimen and Fig. 46, in Ritchie's text.

Preserve this specimen for further use in a glass fruit jar in a 5% formalin solution. Make a small slit in the stomach and remove its contents and force the formalin solution down into the intestines so as to prevent decay. If the cat is not fed for twenty-four hours the stomach and intestines will not be gorged with food.

The Nervous System. Take a frog or a toad and kill it with ether or chloroform. Before its body has time to get stiff dissect off the top of the head and expose the brain. Prick the brain very lightly at different places with the point of a pin or a fine wire and note the resulting movements of the different parts of its body. Next, remove the viscera. On the dorsal wall of the ventral cavity of the body are the two large. white sciatic nerves running to the hind legs. Stimulate these nerves by pricking them lightly with a pin and note the muscular contractions caused in the hind legs. Then look carefully on each side of the spinal column and you will find adhering to the dorsal wall a small chain of ganglia with delicate nervous connections. This is part of the symathetic nervous system.*

Foods and Energy. Chemical processes play a great part in the digestion of foods. There are many mature students of free-school age in Texas who have never had an opportunity to observe a chemical reaction. For their benefit the following demonstration will be very helpful:

a. Fill a test tube to a depth of one inch with iron filings or carpet tacks. Add concentrated hydrochloric acid until they are covered to a depth of one-fourth inch. Notice the vigorous reaction that immediatly sets in as the gas bubbles begin to rise. After one minute notice that the test-tube has grown perceptibly warmer from the heat that has been chemically liberated. Heat is a form of energy.

b.

c. Write the chemical symbols for water (H_2O), for starch ($C_6H_{10}O_5$), and for common sugar ($C_{12}H_{22}O_{11}$). Explain to the class that H stands for hydrogen, O for oxygen, and C for carbon. Call the attention of the class to the fact that if H_2O is water, the $H_{10}O_5$ of starch and the $H_{22}O_{11}$ of the common sugar must also be water. In other words, starch and sugar are composed of carbon and water. To further simplify and demonstrate this fact take a teaspoonful of sugar and heat in the stove shovel. The water will pass off as steam, leaving the carbon behind as crisp black bubbles.

When the carbon of sugar is consumed by the body, it produces chemical heat to keep the bady warm. It is the carbon of the wood and coal that produces most of the heat in the stove. When food is digested in the body it gives off heat in a way analogous to that when iron fillings are acted upon by hydrochloric acid.

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*The observations as outlined above furnish an excellent introductory lesson to a study of the brain and the nervous system. They shoul be prepared in advance and precede all lesson assignments on the nervous system. They should lead up to the lesson assignments. If properly used they will give a new insight, awaken interests, and enable the pupil to read the assignments more understandingly.

Do not say these things are not practicable. They are. The author has done them in country schools—some of them one-teacher schools, too. This method of instruction gets results when the didactic textbook method is destined to fail.

Tests for Different Foods

a. *Starch.* Boil a tablespoonful of starch in half of a teacupful of water until it is dissolved and a thin paste is formed. Fill a test-tube to the depth of one inch and add a drop of iodine. The starch paste almost instantly turns to a dark blue color. If it is very dark dilute with water and a bright blue color is produced.

Test pieces of potato, apple, cabbage, turnip, and bread for starch by bringing them in contact with the stopper from the iodine bottle.

b. *Protein.* Take the white of an egg and beat until it pours freely. Then stir it into one-fourth of a teacupful of water. Put a small amount of this solution into a test-tube and add three or four drops of nitric acid. A white precipitate is formed. Heat over the alcohol flame and the precipitate turns yellow. Cool the test-tube and add ammonia, a few drops at a time until the precipitate turns orange. This is a good test for protein.

c. *Grape Sugar.* Dissolve a stick of cheap candy in a half teacupful of water. Pour a small quantity of this solution into a test-tube and add twice the amount of Fehling's solution. Boil the mixture slowly over the alcohol flame. The red color indicates the presence of grape sugar.

Do not use cane sugar in this experiment. Cane sugar is chemically different from grape sugar and does not respond to the Fehling's test for sugar.

These three experiments can be performed in one lesson period if the teacher has all the materials prepared and ready. They should precede and lead up to the discussion of a balanced ration.

It is best for the teacher to prepare the materials and perform these experiments at least one time each before attmepting them in the presence of the class. In other words, *be sure* that the experiment will work before attempting it before the class.

Getting the Food Into Solution. Food must be dissolved and put into solution before it can be absorved and assimilated by the body. To illustrate what is meant by getting food into solution dissolve a teaspoonful of sugar in a teacup of warm water. The sweet taste of the water will indicate the presence of sugar in solution.

Which will go into solution the more easily, coarse particles of salt or an equal amount of finely pulverized salt? Take two glasses of warm water and put a teaspoonful of fine salt into one, and a teaspoonful of very coarse salt into the other, and stir for a quarter of a minute each. Which is the easier to dissolve? How does reducing the food to small particles before swallwoing it aid in digestion?

Dietetics. When food is burned in the body it gives off heat. The unit for measuring heat is called the calorie. A calorie is the amount of heat required to raise the temperature of one liter (about one quart) of water one degree centigrade. The number of calories of heat required per day is not the same for all individuals. A child seven or eight years old will require from 1500 to 1800 calories per day, a man doing sedentary work about 2720 calories, and a man at hard physical labor 4080.

But all foods do not produce the same amount of heat when consumed by the body. One pound of butter produces 34 times as much heat as a pound of tomatoes, and one pound of bacon 8.5 times as much as a pound of potatoes. Although one pound of bacon contains 8.5 times as much fuel as a pound of potatoes, if bacon is selling at 40 cents per pound and potatoes at $2.00 per bushel, $1.00 will buy more fuel invested in potatoes than it would invested in bacon. At these figures one dollar's worth of bacon will contain approximately 6450 calories while one dollar's worth of potatoes will contain approximately 9000 calories.*

This table shows the food values in calories of one pound of each one of the foods listed.

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*Compiled from the table on page 10, of University of Texas Extension Bulletin No. 1716, The Principles of Menu Making, by Miss Anna E. Richardson of the School of Domestic Economy. The teacher should secure a copy of this bulletin for each member of the class and use it as a basis for two or three lessons in dietetics.

	Food value of one lb. in calories	Present market price per lb.	Food values in calories		
			Protien	Fat	Carbohydrates
Dried apples	1331	----------	29	90	1212
Butter	3474	----------	18	3456	----------
Beef	900	----------	290	710	----------
Bacon	2579	----------	171	2408	----------
Banana	290	----------	14	16	260
Kidney beans	1569	----------	412	74	1083
Dried lima beans	1599	----------	331	62	1206
Carrots	160	----------	17	8	135
Cabbage	177	----------	36	15	126
Corn meal	1614	----------	167	77	1370
American cheese	1997	----------	520	1471	6
Eggs	597	----------	216	381	----------
Cream of wheat	1649	----------	200	58	1391
Sifted flour	1881	----------	203	320	1358
Hominy	1603	----------	150	25	1428
Milk	317	----------	58	166	92
Rolled oats	1817	----------	305	299	1213
Potatoes	300	----------	32	4	264
Peanuts	1882	----------	354	1190	336
Rice	1600	----------	146	12	1442
Sugar	1817	----------	----------	----------	1817
Tomatoes	102	----------	22	8	72

Consult the local grocer and ascertain the prices of all the foods listed in the table given above. Fill in the prices in the column left blank for that purpose. Have each pupil copy the entire table including the prices and the caloric values of each food listed in it. Using this table as a key have them solve the probelms given below. This is a good opportunity to correlate physiology with a lesson in arithmetic.

1. At present prices, which contains the more fuel, a dollar's worth of bacon or a dollar's worth of beans; a dollar's worth of corn meal or a dollar's worth of wheat flour; a dollar's worth of sugar or a dollar's worth of potatoes; a dollar's worth of rice or a dollar's worth of Lima beans?

2. Which contains the greatest amount of protein, a dollar's worth of bacon, beef, beans, cheese, or peanuts?

3. Which contains the greatest amount of carbohydrates, a dollar's worth of potatoes, rice, sugar, wheat flour, or corn meal?

4. Which contains the greatest amount of fat, a dollar's worth of bacon, butter, peanuts, or cheese?

5. The chief foods in meat are protein and fat. Could eggs, cheese, beans, and peanuts be substituted for meat in a ration? If so, why?

6. Two men went into a restaurant and ordered dinners. One ordered eggs, cheese, chili, baked beans, and beefsteak. The other ordered butter, rice, hominy, potatoes, and apple dumplings. Were these meals well balanced? If not, why not? Consult Ritchie, page 124.

7. A poor family lived a year on very fat bacon, wheat flour, and cane syrup. What did this ration lack? Was it an economical ration?

8. Collect the following amounts of food in big-mouthed bottles and bring to the school museum to be retained as part of the permanent equipment of the school: 1.2 oz. dried apples, .62 oz. bacon, 1 oz. Lima beans, .99 oz. corn meal, .8 oz. American cheese, 1 oz. sifted flour, .88 oz. rolled oats, .85 oz. peanuts, 1 oz. rice, and .88 oz. sugar.* Impress upon the pupils that

*University of Texas Extension bulletin No. 1716, p. 10.

each of these amounts have the same fuel value, that is, each one will produce 100 calories of heat when burned in the body.

The Ciirculation. A. Secure the heart of some large animal and bring before the class for study. Identify the blood vessels connecting with the heart, and the different chambers and valves within it. Call special attention to the valves and the numerous white cords that hold them in position. Soak the heart in a one per cent formalin solution over night. Preserve in a five per cent formalin solution for future use.

Respiration. a. Just before the class period have two boys remove the lungs of a cat or a rabbit with the trachea attached. While the lungs are still fresh and pliant insert a quill or a glass tube into the trachea, and inflate the lungs by blowing your breath into them just as you would inflate a small rubber baloon. Then punch the walls of the trachea firmly together with thumb and finger just beyond the end of the inserted tube in the same way you would mash the walls of the neck of a rubber baloon together to keep the air from escaping. This is to prevent mucus being blown back into the mouth when the air is exhausted from the inflated lungs. Repeat as many times as desired.*

b. Test the lung capacity of the pupils in the following manner: Procure from the drug store a large bottle with a capacity of one gallon or more. Fill it with water until it is running over. Cover the mouth of the bottle with a small piece of window-pane or flat tin. Invert the bottle into a large pan containing about one inch of water in the bottom. While the mouth of the bottle is resting on the bottom of the pan remove the piece of tin or window-pane which was used to prevent spilling any of the contents of the bottle while it was being inverted into the pan. Incline the bottle so as to give enough room between its mouth and the bottom of the pan for the insertion of a small rubber tube well up into the neck of the bottle. Then have some student inhale all the air his lungs will hold and blow into the free end of the tube until his breath

*It would be better to perform this demonstration without removing the lungs from the thoracic cavity of the cat's body, but the teacher's lack of skill in doing the necessary dissecting, and the conditions under which the work has to be done in most country schools make it inadvisable in most instances.

is exhausted. This will force the water out of the bottle, replacing it with air from the lungs. At the end of the experiment the volume of the air above the water remaining in the bottle is equivalent to the capacity of the experimenter's lungs.

The difficulty of computing the volume of the air in the bottle exhaled from the experimenter's lungs can be greatly simplified as follows: Before beginning the experiment take a standard pint measure, 29 cu. in., level full of water, and pour into the bottle. Mark the place to where the water comes, 29 cu. inches. Pour in another measureful and mark the place to where the water then comes, 58 cu. in.; for the third measureful mark, 87 cu. in.; and so on until the bottle is filled. Use paint for marking these scale numbers on the outside of the bottle and the figures will not come off when wet.

Insert a short piece of glass tubing into the free end of the rubber tube for a mouthpiece, and each time it is used wash it thoroughly before permitting another pupil to take it into his mouth.

c. Carbon dioxide in exhaled air: Put a handful of lime into a quart measure of water and allow it to stand over night. The lime will settle to the bottom. Draw off the clear water standing above the lime into another vessel, being very careful all the time not to stir up the lime from beneath. Fill a test-tube to the depth of one inch with this clear limewater, and with a quill or a glass tube blow the breath through it for one-half minute. The white precipitate indicates the presence of carbon dioxide.

d. Carbon dioxide, a product of combustion: Put two tablespoonfuls of lime water in a quart fruit jar. Tie a small piece of cotton on the end of a pencil, saturate it with wood alcohol, ignite with a match, and lower into the jar until the blaze goes out. Quickly cover the mouth of the jar with the lid or with the open hand and shake vigorously for a few seconds. The limewater will be turned to a milky white. Why?

In making this demonstration wood alcohol makes no smoke and for that reason is perferable to gasoline, a candle, or other combustibles that might be used.

The Kidneys and the Skin. a. With scissors and sharp scalpel dissect out the kidneys of a cat or a rabbit with the renal vein, renal artery, and ureters attached. Preserve in a 5% formalin solution and have ready for use when needed in class work.

b. To illustrate the cooling effect of evaporation upon the skin, apply a drop or two of wood alcohol, ether, or gasoline to the hand of each pupil.

c. To illustrate that evaporation takes place rapidly in a draft of air lay a wet hankerchief loosely over the hand and fan vigorously for a half minute and note the cooling effect. Why do clothes on the line dry more rapidly on a windy day than on a still day? How is one's skin cooled by the use of a fan on a hot day?

The Nervous System. a. Dissect out the brains of rabbits, cats, rats, and birds, and preserve in a 5% formalin solution. Get at least one brain with as much of the medulla and spinal nerve attached as possible.

b. Carefully remove the viscera of a toad or a frog so as to get a clear view of the large white sciatic nerves running to the hind legs on the dorsal side of the abdominal cavity and the delicate chain of ganglia of the sympathetic nervous system on both sides of the spinal column. Preserve in a 5% formalin solution for future use.

c. Harden the medulla and the spinal cord of a large cat in a 5% formalin solution and make cross-sections showing the arrangement of the gray matter and the white matter as exhibited by Ritchie, Fig. 101, page 218.

The Special Senses. a. In a quiet room take a tapeline and a watch and see how far away each pupil can hear the ticking of the watch. A pupil that hears very poorly should be given a seat near the front.

b. Any oculist will be glad to give you some Snellen's test cards and show you how to test for far-sightedness, near-sightedness, and astigmatism.

c. Dissect out the eye of a cat with the optic nerve and at least one of the muscles that move the eye attached. Preserve in a 5% formalin solution several days. Keeping in mind the diagram given by Ritchie, Fig. 124, page 261, proceed as follows: Make an incision across the cornea; remove the aqueous humor; catch a good deep hold on the iris with a pair of tweezers and the entire front portion of it resembling a very thin leather disc with a round hole in the center can be removed. Then the lens, like a hard transparent button can be easily removed.

Disease Germs. This demonstration was one time performed by a teacher in a Texas country school without a laboratory. An Irish potato was boiled and then sliced into four pieces one-quarter of an inch thick with a clean sharp knife that had been sterilized in the flame of an alcohol lamp. The slices of potato were then put on pieces of sterilized window-pane as large as a man's hand. One of the slices was inoculated by a boy touching his dirty fingers to it for ten seconds, another was inoculated by making two dim scratches across it with a pin that had been dipped into some stagnant water containing some partially decayed hay, the third one was inoculated by bringing the top side of it in contact with the schoolroom floor for a few seconds, and the fourth one was not inocualted at all. They were then covered with inverted glass tumblers so as to exclude the bacteria of the outside air and set away on a dark shelf for three or four days.

The teacher then explained that each little germ and spore on the inoculated potato would have a large family in a few days. She further explained that the parent germs and spores taken individually were too small to be seen, but the entire colonies that would spring from them would be visible as mouldy-looking spots. Three or four days later the inoculated pieces of potato were brought before the class and uncovered. The one the boy touched with his dity fingers showed thirteen bacterial colonies, the one brought in contact with the floor nine colonies, the one inoculated from the hay infusion was bristling with what the children called mildew, and the one not inoculated at all was still clean and fleecy white with only two very small spots hardly so large as pinheads on it.

This is a very simple demonstration of how numerous bacteria are and how rapidly they multiply. Any careful teacher can perform it.

The Microscope. But few country schools in Texas are equipped with a microscope. To meet this deficiency the author has on several occasions while teaching in the country borrowed a microscope for a few days from the nearest high school laboratory. One time he borrowed a microscope for two days from a local doctor practicing medicine in a nearby village. Favors of this sort are easy to obtain when the persons owning such instruments are sure you know how to use them without doing them damage and will be punctual in returning them.

There are quite a number of teachers in the country and village schools who learned to do elementary microscopic work while attending high school, college, or state normal. These teachers should provide the childern they teach an opportunity to see down into the world of diatoms just one time. It will be a great revelation to them. It will form a bright chapter in their education. Some of them will never have the opportunity unless the teacher provides it. It is worth the time and effort it takes.

The following simple observations can be easily made:

a. Place some saliva on a slide and with the low-power lens find the small unicellular, disc-like diastase ferment that assist in digesting the starchy foods.

b. In like manner take some foaming molasses, foaming preserves, or apple cider that is in process of fermentation and find the little round ferments.

c. With the edge of scalpel or knife blade scrape some slime from inside the cheek and spread very thinly on a moist slide and find the epithelial cells. They are irregular and almost transparent, but can be seen without staining. Some diastase ferments will also most likely be found in the saliva and mixed among the epithelial cells.

d. Examine the foot and proboscis of a fly. Examine the feathery dust from the wing of a moth or butterfly.

e. Put a handful of hay in a small basin of water and set aside in some warm place for a few days. Place some of the scum on the surface of the water on a slide and examine for paramesium and other active animalculae. Paramecium are rather large one-celled animals and can be seen swimming about quite actively. In fact, they seldom stay still long enough at one time to be examined carefully by the eye of the observer. To prevent them from swimming out of vision and make a closer examination possible kill them with a 2% ascetic acid solution. Then with a little pains you can find individuals in process of division as indicated by Ritchie, Fig. 3, p. 6.

f. Examine a drop of human blood spread very thinly on a slide.

g. The usual method of making a microscopic examination of the circulation of the blood is to observe the movement of the blood through the arteries, veins, and capillaries in the thin transparent web of a frog's foot. A better method is to secure a tadpole and wrap it in wet cotton, leaving the wafery transparent end of the tail exposed for examination by the microscope. The tadpole is not so active as the frog and will get out of focus less often.

PHYSICAL GEOGRAPHY

In physical geography as in the other elementary sciences, teachers do not stay close enough at home in their instruction. They spend much time making analyses of the machinery of the solar system, and studying tides, ocean currents, equinoxes, and the like, but overlook most of the interesting phenomena of nature near by. The object of the present chapter is to call attention to some simple experiments for physical geography that are within easy reach of most every determined teacher.

List of Material Needed

(Total cost about $1.50)

Bar magnet.
Powdered alum or powdered copper sulphate, 2 oz.
Test-tubes, 1 doz.
Rubber stopper to fit test-tubes and having one hole 1/8 inch in diameter through it.
Two or three short pieces of glass tubing 1/8 inch in diameter.
One capillary tube (a broken thermometer tube will suffice).
Two or three feet of rubber tubing 1/8 inch in diameter.
Collection of wide-mouthed bottles and glass fruit jars.
Alcohol lamp.
Wood alcohol, 1 pt.
Collection of rocks, ores, minerals, and fossils.
Soils: corse, clean sand; pure clay; residual soil.

Most of this equipment can be procured from the teacher of science at the nearest high school and from the drug store.

Magnetic Phenomena. Take a small piece of dry cork or dry pith of corn stalk as big as a pea and suspend on a silk thread one foot long. Take a guttapercha comb or a glass rod that has been thoroughly cleaned with gasoline or wood alcohol and rub vigorously on a dry woolen coat sleeve for ten seconds. Then bring it within an inch or two of the suspended cork or pith ball. The ball will be attracted to the object that has been electrified by rubbing on the dry woolen fabric and will cling to it tightly. Give the ball plenty of time to absorb the charge from the electrified object. When sufficiently charged it will be repelled by the object that at first attracted it. It will be repelled to the distance of an inch or so if the atmosphere in the room is very dry. If the pith balls are not available, very small bits of paper will do quite as well.

b. To make a simple magnetic needle take a cambric needle, or preferably a small steel wire, and magnetize it by rubbing one end of it against the north pole of a bar magnet and the other end against the south pole. Then stick it through a small disc or cork and make it float in a horizontal position in a saucer of water. If there are no air currents in the room and the water in the saucer is not jarred by heavy footsteps on the floor or otherwise disturbed, the needle will soon adjust itself and assume a north-south direction. If the needle has a tendency to drift to one side and come in contact with the edge of the saucer anchor it in the center with a small weight and a silk thread.

Which pole of the magnet will be attracted to the north? Which to the south?

Bring the north pole of the bar magnet within six inches of the south end of the floating magnet. What happens? Why? Repeat the experiment by bringing the south pole of the bar magnet within six or eight inches of the north end of the floating magnet.

In performing this experiment see that the saucer and the floating magnet are removed three or four feet from all iron and steel objects. Sometimes a pocket knife in one's pocket will disturb the needle until it will not settle down to a steady position. The nails in the table may even deflect it from a true north-south direction.

Directions. a. Find and locate the Great Dipper and the North Star.

b. Establish a north-south line by measuring a shadow and observing its movements and directions during one school day. To do this take a straight rod five or six feet long and drive it into the ground in a perpendicular position. Select a place where the ground is as nearly level as possible. Beginning at

9:00 A. M. drive a small peg into the ground at the end of the shadow. Repeat this every thirty minutes until 4:00 P. M. The shadow will be shortest in the middle of the day just as the sun passes over the meridian where the observations are being made. When the shadow is at its shortest it will be pointing directly north.

This experiment can be performed just as well on top of a perfectly level table in the sunshine. Cover the table with a clean sheet of paper. Near the center of it place some object the length of a knitting needle in a perpendicular position. At thirty minute intervals during the day mark the ends of the shadows it subtends by driving pins into the top of the table. At the end of the day take a pencil and draw a line through all the points where the pins have been driven. This line will be a curve. Note the point in this curve nearest to the base of the object subtending the shadows. A straight line drawn connecting this point with the base of the upright object producing the shadows will lie in a north-south direction. Extend the length of this line indefinitely. Find some objects about the playground that lie in the same line with it and designate them as marking a north-south line for that locality.

The Crust of the Earth. 1. To demonstrate the difference between a substance in solution and a substance in suspension:

a. Take two pint bottles and fill with water adding to one a teaspoonful of sugar and to the other a teaspoonful of sand. Shake both of them vigorously for a few seconds. The sugar soon dissolves and goes into solution. The sand remains suspended and undissolved giving the water a muddy cast.

b. Over an alcohol flame evaporate a drop of water from the well or hydrant on a clean watch crystal or a piece of broken window pane. Do the same with a drop of distilled water or fresh rain water. Which leaves the greater stain or residue on the glass? Why? Is the hard crust on the inside of the teakettle formed from mineral matter in solution or from mineral matter in suspension? Would this crust be formed if distilled water were used? If not, why not?

c. Carefully examine a piece of sandstone. Use a magnifier if you have one. Compare the fragments with clean sand. What fills the spaces between the grains? How was the sandstone probably formed? What part of it was deposited from solution? What part from matter in suspension?

d. If you have laboratory scales, weigh equal volumes of salt water and distilled water. Which is the heavier? Why?

The formation of crystals from a substance in solution. a. Take a small quantity of saturated salt solution and boil slowly until the water is completely evaporated and note the formation of salt crystals.

b. Put some twine strings into a vessel containing a solution of alum water to which an excess of powdered alum has been added. Set this aside for several days and as the water evaportes note the formation of crystals on the strings. Perform the same experiment using copper sulphate. Note the shape and size of the crystals in both cases. Examine quartz, and broken pieces of marble and granite with the magnifier. Do the crystals imbeded in the granite indicate that the granite was one time in a liquid state? If so, what was its probable temperature at that time?

Rocks, Ores, and Minerals. a. Bring to the school museum a collection of all the rocks, ores, and minerals native to the locality of the school. To this collection add such others as may be obtained from abroad. It should contain specimens of sandstones, limestone, marble, shale, granite, quartzite, basalt, anthracite coal, bituminous coal, lignite, crude oil, etc.

b. Secure several pieces of limestone. Which is the harder, limestone or sandstone? Which is the easier to scratch with glass? Which was formed in the quieter water? Which was formed mainly from matter in suspension and which from matter in solution in water?

c. Secure as many specimens of shale as possible. Note the planes of stratification and account for them. Note the impressions of fossilized plants and animals.

d. Collect some water-worn pebbles and account for their plain smooth surfaces. Note the character of the pebbles and determine the locality whence they came.

e. Examine a piece of granite with a lens. Test its hardness.

Are there any evidences of stratification? Is it of igneouse or of aqueous formation? Account for its crystaline structure?

f. If possible, secure specimens of anthracite coal, bituminous coal, and lignite and bring to the class. Carefully examine the structure of each. Have the pupils learn all they can about the origin of each.

g. Put some small pieces of soft coal into a test-tube and cork with a one-hole stopper fitted with a glass tube of small bore that has been drawn to a very fine point. Heat the coal in the test-tube so as to drive off the gas and with a match ignite the small gas jet at the end of the glass tube.

Soils. a. Have in the school museum labeled samples of sand, clay, forest soil, and residual soil taken from the wall of some cave or cliff.

b. Put a teaspoonful of each soil into distilled water or fresh rain water in test-tubes and let it set over night. Take a drop of the perfectly clear water from above the soil in each test-tube and put it on a piece of broken windowpane and evaporate in the alcohol flame. Note the stain made on the glass from the residue in each instance. Which soil is the most soluble in water? Which the least? Which is the best for plants in this respect?

c. Stratification: Take a deep glass jar or a large test-tube and fill one-fifth full of equal parts of fine pebbles, sand, and fine clay. Fill about two-thirds full of water and shake vigorously. Put aside and allow to settle. Note the stratification. Which material is sorted out first?

Atmospheric Pressure. Secure from the local drugstore a small tin can with an open mouth that can be fitted with a stopper—an ether can. Put in a small amount to water and raise to a boiling point for a minute or so. Cork and set aside to cool. The cooling may be hastened by pouring on cold water. Notice that on cooling the sides of the can tend to collapse. Why? Because the steam on the inside has been condensed leaving a partial vacuum and the weight of the air on the outside tends to crush in the sides of the can. Why is the cork so difficult to remove?

To demonstrate why water boils at a lower temperature in a high altitude than at sea level: Fill a test-tube one-half full of water and raise to the boiling point over the alcohol flame. Remove from the flame, cork tightly, and wait a second or two for the boiling to cease. Dip the corner of a handkerchief into a basin of cool water and wrap it around the top end of the test-tube. Violent boiling again ensues. Why?

Explanation: At sea level where the atmospheric pressure is approximately 15 pounds to the square inch, water boils at 212° F. On top of a high mountain where the atmospheric pressure is less, water boils at a lower temperature. The cool handkerchief in this experiment condenses the steam above the water in the corked test-tube thus producing a partial vacuum and reducing the pressure. Consequently, it boils again, but at a lower temperature.

Atmospheric Moisture. a. Take two pieces of window glass. Put an equal number of drops of water on each. Place one of them in a draught and the other where the atmosphere about it is very quiet. If the atmosphere is quiet and there is no breeze, fan one of them until the water evaporates. What is the effect of a moving air current on evaporation? Why will the wet fields dry more on a windy day than on a still day?

Fill a test-tube half full of water. Put the same quantity of water in a tin plate. Set them both in the sun. Which will evaporate first? How does the amount of surface exposed to the air affect evaporation?

c. Put equal amounts of water in two very small vessels. Invert a table glass over one and leave the other exposed. From which vessel does the water evaporate the more rapidly? Notice how the moisture condenses on the inside of the glass. Where is the atmosphere the more humid, on the inside of the glass or on the outside of it? How does moisture in the atmosphere affect evaporation?

To produce a miniature rain storm: Take a clear, open-mouthed glass jar filled one-third or one-half full of alcohol. Set this inside of some convenient vessel of water and raise to the boiling point. Remove this double boiler from the fire and set a tin cup of cracked ice on top of the jar of alcohol. After a short time a fine mist or shower of precipitated alcohol can be seen going on inside the jar. If the bottom of the cup used for a condenser fits closely on the top of the jar and is kept perfectly still a small cloud can be distinctly seen in the top of the jar. Explain.

The amount of rainfall: If a rain guage is not available for the school, use a deep open-mouthed tin can. Put it in an open place free from buildings and other obstructions and measure the amount of rainfall from time to time with a ruler. Keep a record of the dates and amounts of rainfall through the entire year. What is the annual rainfall for the locality? What months have the heaviest rainfall?

To prove that a solid expands when heated: Take two very small copper or steel wires about the size of a small guitar string and one or two feet long. Stretch them between tacks driven into the posts of a chair and arranged so the two wires will be parallel to each other, about one-fourth of an inch apart, and one directly above the other. Wrap the one beneath with a cotton string, or better still with a narrow strip of cotton cloth. Saturate this wrapping material with wood alcohol. See that the wire above is good and taut. Ignite the alcohol with a match. As the taut wire above becomes heated it will expand in length and get very slack and loose.

Repeat this experiment by stretching a wire while very hot and then cooling it with cold water. In this way the wire will be stretched very taut and may even break from the force of contraction as the heat leaves it.

Why do blacksmiths sometimes heat wagon tires before putting them on?

A passenger train was wrecked in East Texas one hot August day last year. The newspaper report said it was due to a "sun kink" in the track. What happened?

Why do track-layers always leave a small space between the ends of the rails in railroad construction?

Why do telephone wires get taut and sometimes break in winter?

To prove that a liquid expands when heated: Fill a test-tube completely full of water that has been colored with ink. Cork with a rubber stopper that has a small round hole through it. Through this hole insert a tight-fitting capillary tube (a piece of broken thermometer tube will answer) down into the water beneath. Heat over the alcohol flame. As the colored water becomes warm you can see it rise in the capillary tube just as the mercury rises in the thermometer on a hot day.

Does the power of heat to expand a given volume of water have any relation to ocean currents? If so, how?

Explain how heat stored up in water is sometimes transported by ocean currents for hundreds of miles and warms lands that would otherwise be cold? Give example?

To prove that a gas expands when heated: Take an empty test-tube and stop with a rubber stopper that has a hole through it. Insert into the hole a short tight-fitting glass tube to which a rubber tube a foot long has been attached. Put the free end of the rubber tube into a glass of water. Heat the test-tube gently in the alcohol flame. As the air becomes heated it expands and air bubbles will rise from the free end of the rubber tube submersed in the glass of water. Allow the test-tube to cool, keeping the end of the long tube in the water. Explain why the water rises in the tube.

AGRICULTURE

Agiculture has been dignified with a place in the curriculum along with the other courses, but before it can ever succeed as a school subject the teaching must be less formal. More emphasis must be placed on material things, and books and other printed matter used only as aids in studying them. The following are a few demonstrations and experiments that can be performed by any alert teacher.

1. *What Becomes of the Rain.* Water falls upon the ground in the form of rain. But it does not remain on the surface very long. Part of it goes into the ground, part of it may run off, and part of it evaporates.

Water vapor is invisible. The wet, muddy road will dry out on a bright breezy day and no human eye can see how it takes place. Even when raindrops as precious as pennies should be stored in the soil to nourish the thirsty growing crops, the rainfall escapes and goes back to the dry air unseen. If the eye could see just what takes place, many farmers would change their practices of soil cultivation.

To illustrate what takes place when moisture escapes from the soil and goes back to the air, make the following demonstration:

a. Shake the ammonia bottle and remove the stopper with a drop or two of ammonia on it. Explain to the class that the ammonia on the stopper is evaporating and will soon be gone. With the hydrochloric acid bottle removed four or five feet from the ammonia bottle repeat the performance and explain that the acid on the bottle stopper is also passing away in invisible form. Then bring the stoppers of the two bottles within an inch of each other. What is really taking place suddenly becomes visible. When the vapors from the two stoppers meet they form a small white cloud.

b. The portion of the water that sinks into the soil forms small capillaries among the particles of soil as it goes down. Much of it later escapes from the soil through these same capillaries. To prevent this loss of moisture through the soil capillaries farmers often resort to shallow plowing. Shallow plowing clips off the top ends of the capillaries and forms a dust mulch that helps, like the cork of a jug, to hold the water beneath in the soil. The dust mulch blocks its avenue of escape back to the air.

To illustrate how difficult it is for water to pass up through a cushion of dust take a loaf of sugar and put as much powdered sugar as you can get to stay on top of it and set it in a small basin of ink about one-eighth of an inch deep. The ink will rise up through the hard loaf of sugar in three or four seconds, but when it reaches the powdered sugar on top, its upward progress is suddenly checked. It will take several minutes for the ink to get up through the powdered sugar on top.

In performing this experiment a large loaf of sugar is better than a small loaf. If you have the thin, rectangular loaves, place two or three of them side by side and bind them together with a string into a single big thick block. You can get more powdered sugar on top of a big stick loaf than on top of a small thin loaf.

Also, remember that you can not use common granulated sugar in this demonstration. You must have the finely pulverized powered sugar. Powdered starch will do quite as well.

2. *Grafting Wax.* One of the most satisfactory formulas for making grafting wax is to melt one part of beeswax and four parts of resin together and then dilute with denatured alcohol until the desired constituency is obtained. Melt 1½ pounds of beeswax with 6 pounds of resin and when it cools add about 1 quart of denatured alcohol and stir thoroughly. This will usually give satisfactory results, though the amount of alcohol needed will vary with the temperature, more being necessary in cold weather than in warm weather.

Another formula quite commonly used is resin, tallow, and beeswax in the proportions of 1 pound of resin, ½ pound of beeswax, and ¼ pound of beef tallow. If linseed oil is to be used instead of beef tallow, to 1 pound of resin and ¼ pound of beeswax add ½ pint of raw linseed oil. Place the ingredients together in a kettle and melt, then boil for a short while—just long enough to throughly mix the entire mass. Remove from the fire and continue stirring until it cools. Cooling may be hastened by placing the kettle in a basin of cold water.

3. *Grafting Tape.* Take a piece of common domestic and saturate thoroughly in a vessel of melted grafting wax. After it cools tear into long strips three-quarters of an inch wide.

Just here a difficulty will arise in getting the cloth saturated with the melted wax, if the wax be very hot, for the hot wax can not be allowed to come in contact with the bare hands. To overcome this difficulty spread the cloth on top of a table or a wide board and apply the hot wax thinly and evenly with a common bristle paint brush.

4. *Grafting.* Have each pupil provided with a sharp pocket knife, three feet of grafting tape, and a quantity of willow or peachtree switches. Following the suggestions given by Ferguson and Lewis, Fig. 81, p. 136, and Warren, Fig. 27, p. 46, have the pupils devote one class period to practice work in grafting. If there be some farmer in the community who is a successful fruit grower have him give the class a demonstration in pruning, budding, grafting, and transplanting of trees. He will be glad to do so.

There are many methods of budding and grafting. It is not best to attempt teaching all of them to an entire class of children of public school age at one time. It will cause confusion. One or two methods is sufficient. For that reason, and because of their broad range of practical usefulness, I would recommend that the tongue and cleft grafts described in the above-mentioned figures be given first consideration.

5. *Pruning for Blight.* All the limbs or twigs having the least bit of blight must be pruned out carefully. They should be cut a foot or more back of the blight so as to make sure that it is all removed. All twigs and limbs suffering from blight should be cut off very near the part of the tree from which they grow. The ends of the stubs should be coated with white paint or with whitewash. If there be an orchard near the school suffering from blight the teacher should give the pupils a practical demonstration in pruning against it. If

this can not be done specimens of damage from blight should be brought before the class for inspection.

6. *Scoring a Beef Animal.* Provide the students with score cards and have each student locate on a cow each of the points called for in the score card. After all have finished locating the parts, name the parts and ask individual students to locate them. Repeat this several times with those students knowing least about animals. Later have some student start at the head of the animal and name all the parts of the animal he knows. Other students can supply the names of parts left out and correct mistakes. After the parts have been thoroughly learned use two animals letting the pupils study both of them and tell why one is better than the other.

The score card is not advocated as a good thing to use in a show but it serves a very good purpose in getting students to study definite parts and keep them in mind.

7. *Scoring a Dairy Cow.* Score cards are usually used in too matter-of-fact way. They should be made to answer questions. The best questions advocated and the points alloted each are these: (1) Has the cow a strong constitution? 25 points. (2) Has she good blood circulation? 20 points. (3) Has she large and sufficient digestive capacity? 20 points. (4) Has she large udder capacity? 25 points. (5) Has she symmetry and beauty of form? 10 points.

The points of the score card should be rearranged so as to answer these questions instead of leaving them in the divisions of head, forequarter, etc.

8. *The Study of a Simple Flower.* Provide each pupil of the class with a flower of the cotton plant, the morning glory, or the peach, plum, pear, apple, or apricot. Be sure that all the pupils have the same kind of flower for this lesson. It would be confusing for part of them to have cotton flowers and part of them pear blossoms.

Name and locate the following parts: calyx, corrolla, sepals, petals, pistils, stamens, anthers, stigma, and seed capsule. Dissect the flower and examine each part separately, noting the characteristics and defining the function of each part.

9. *The Study of an Insect.* The object of such studies as

this is to sharpen the elementary pupils powers of observation. For convenience a grasshopper may be used. It would be well, when possible, to have each pupil provided with this insect, a pair of tweezers, and a small magnifying glass. Note the following characteristics: each grasshopper has six legs; two antennae or feelers are on the head; there are two large compound eyes; all the legs are attached to the thorax; the wings are attached to the thorax; the ear of the grasshopper is found under the wing; the abdomen is divided into several segment, each segment having small spiracles through which the insect breathes; the mouth parts are made for biting and not for sucking as with the mosquito and the boll weevil; the end of the abdomen of the female is equipped with a strong ovipositor for burrowing into the earth where the eggs are deposited.

What would result if the breathing spires on the abdomen of a grasshopper were sealed up? Would the same thing occur in the case of a wasp or a honey bee? Why do soapy spraying solutions kill plant lice? Why is it so difficult to poison a boll weevil while grasshoppers and caterpillars can be poisoned with comparative ease?

10. *Testing the Vitality of Small Grains.* Take a piepan and place two or three thicknesses of well-moistened cotton flannel cloth or blotting paper in the bottom of it. Then place one hundred oats taken from various points in a larger sample of seed grain on the moistered pieces of cloth in the bottom of the piepan, being careful that no two seeds are in contact with each other. Cover them with two thicknesses of moistened cotton flannel cloth and then cover the whole very closely with another piepan to keep the moisture from escaping. Examine the sample every day, being careful all the time to keep it moist. At the end of a week or earlier, depending upon the temperature at which the test is kept, all the seeds that are viable will have germinated. The ordinary temperature of the room, about 70 degrees, will produce good results.

Count the number of seeds that sprouted and see what per cent of the seed are good. If a farmer pays $1.25 per bushel for seed oats and the germination test shows that only 80 per cent of the seed will sprout, what is the farmer actually paying for viable seed?

11. *Testing Seed Corn.* Bulletin No. 14, issued by the Nebraska Experiment Station, Lincoln, Nebraska, may be had free on request and carries full information for making a germinating box. The "rag doll" corn seed tester is very simple and convenient and full instructions for making and using it, may be had from the International Harvester Company, Chicago, Illinois.